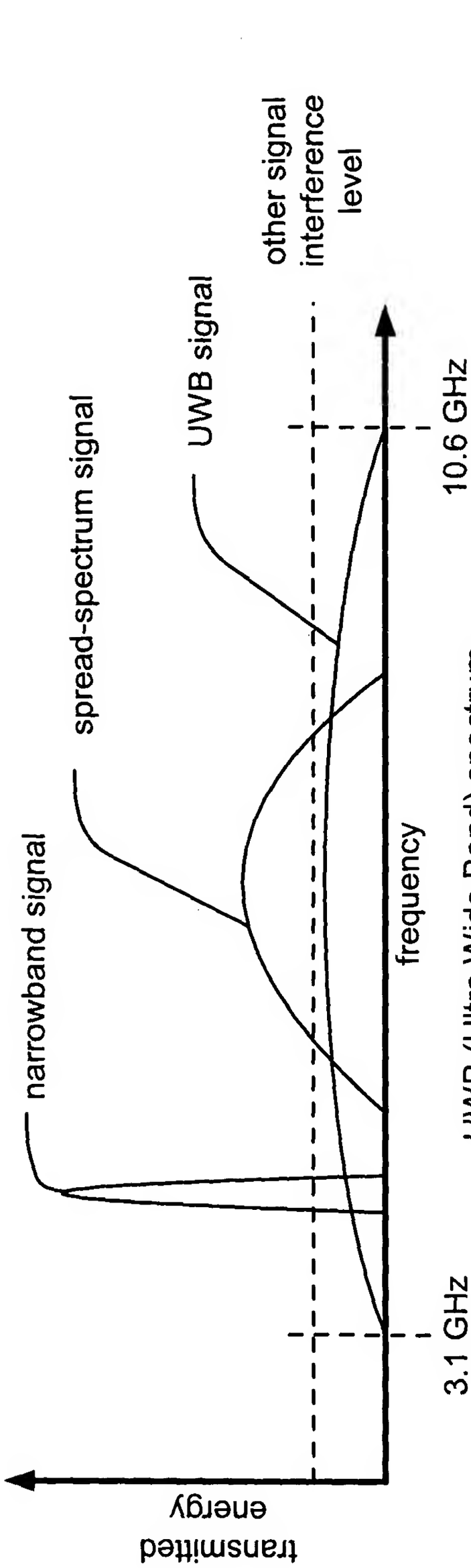

transmitted energy
narrowband signal
spread-spectrum signal
UWB signal
other signal interference level
3.1 GHz
10.6 GHz
frequency
UWB (Ultra Wide Band) spectrum

**Fig. 1A**

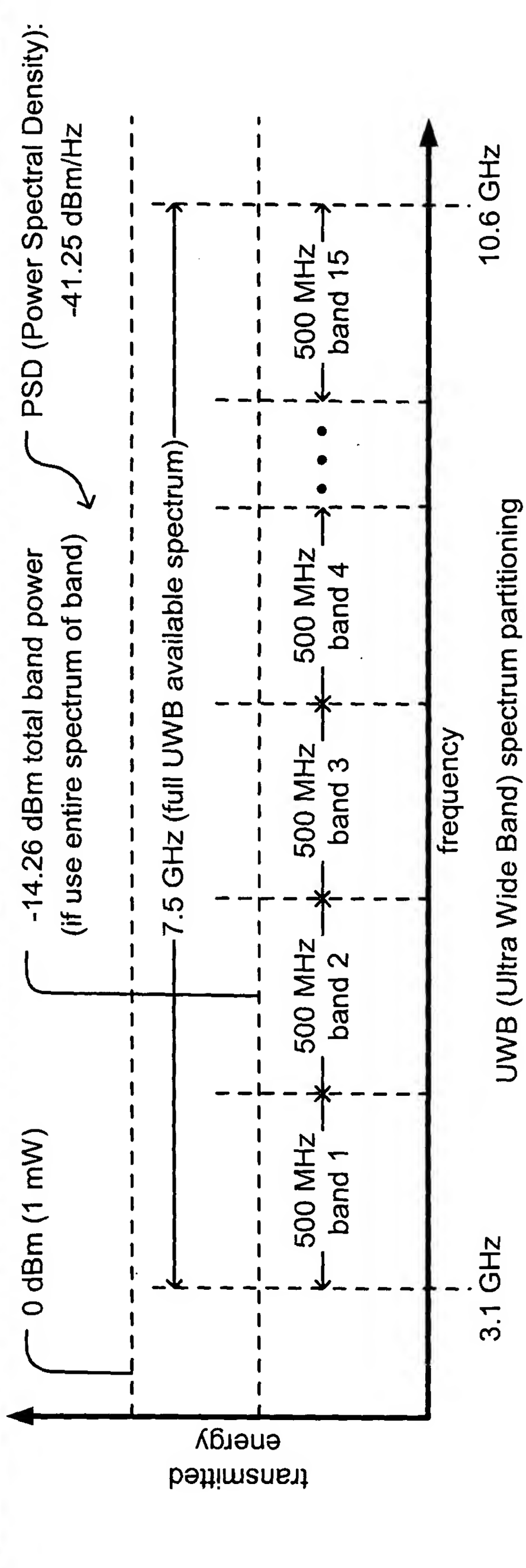
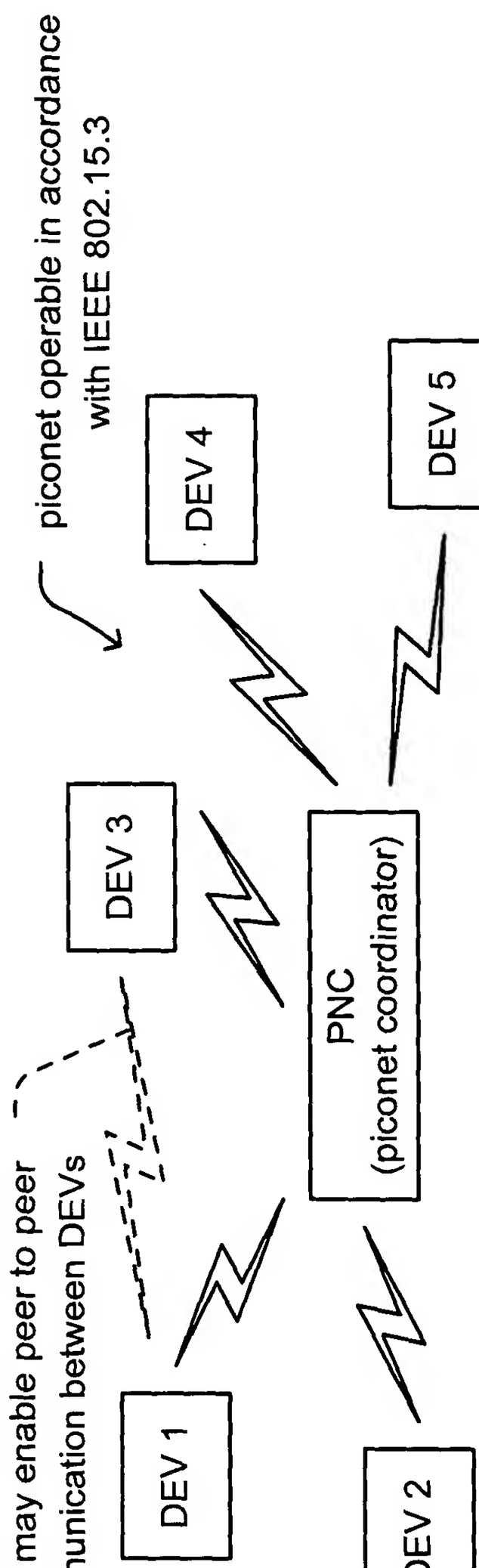
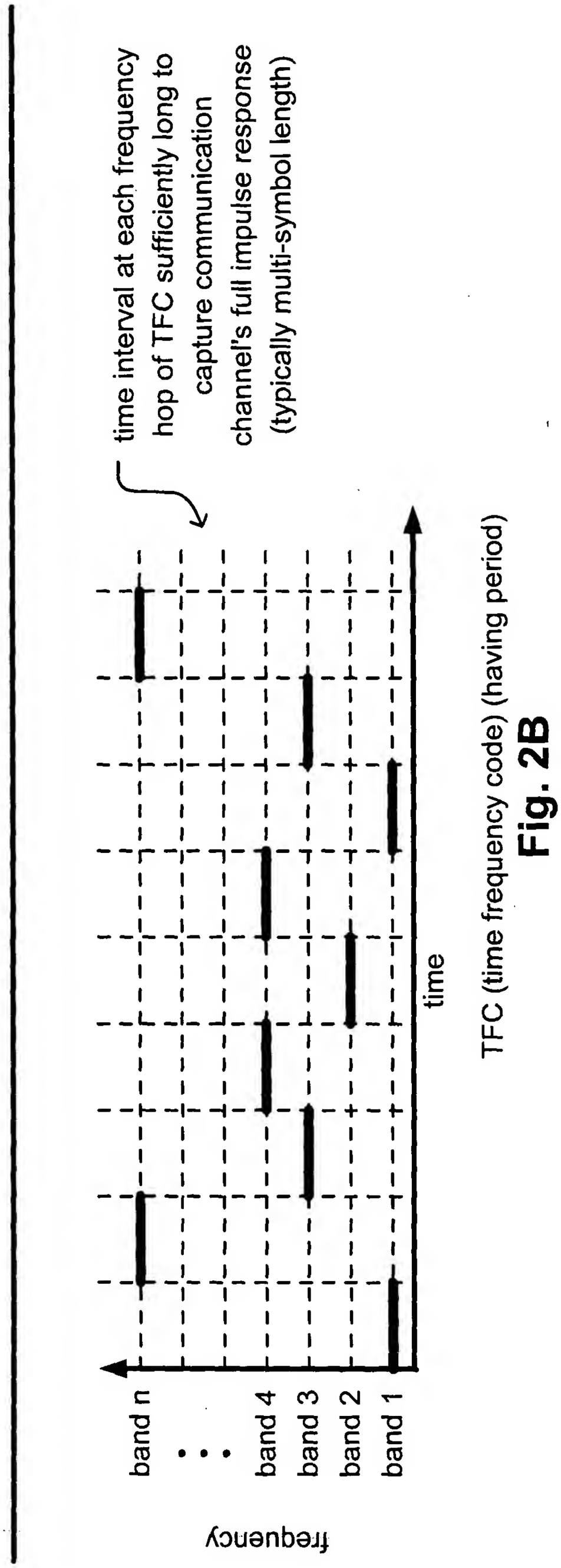

transmitted energy
0 dBm (1 mW)
-14.26 dBm total band power
(if use entire spectrum of band)
PSD (Power Spectral Density):
-41.25 dBm/Hz
7.5 GHz (full UWB available spectrum)
3.1 GHz
10.6 GHz
500 MHz band 1
500 MHz band 2
500 MHz band 3
500 MHz band 4
500 MHz band 15
frequency
UWB (Ultra Wide Band) spectrum partitioning

**Fig. 1B**




piconet (shown in wireless communication system embodiment)

**Fig. 2A**




TFC (time frequency code) (having period

**Fig. 2B**

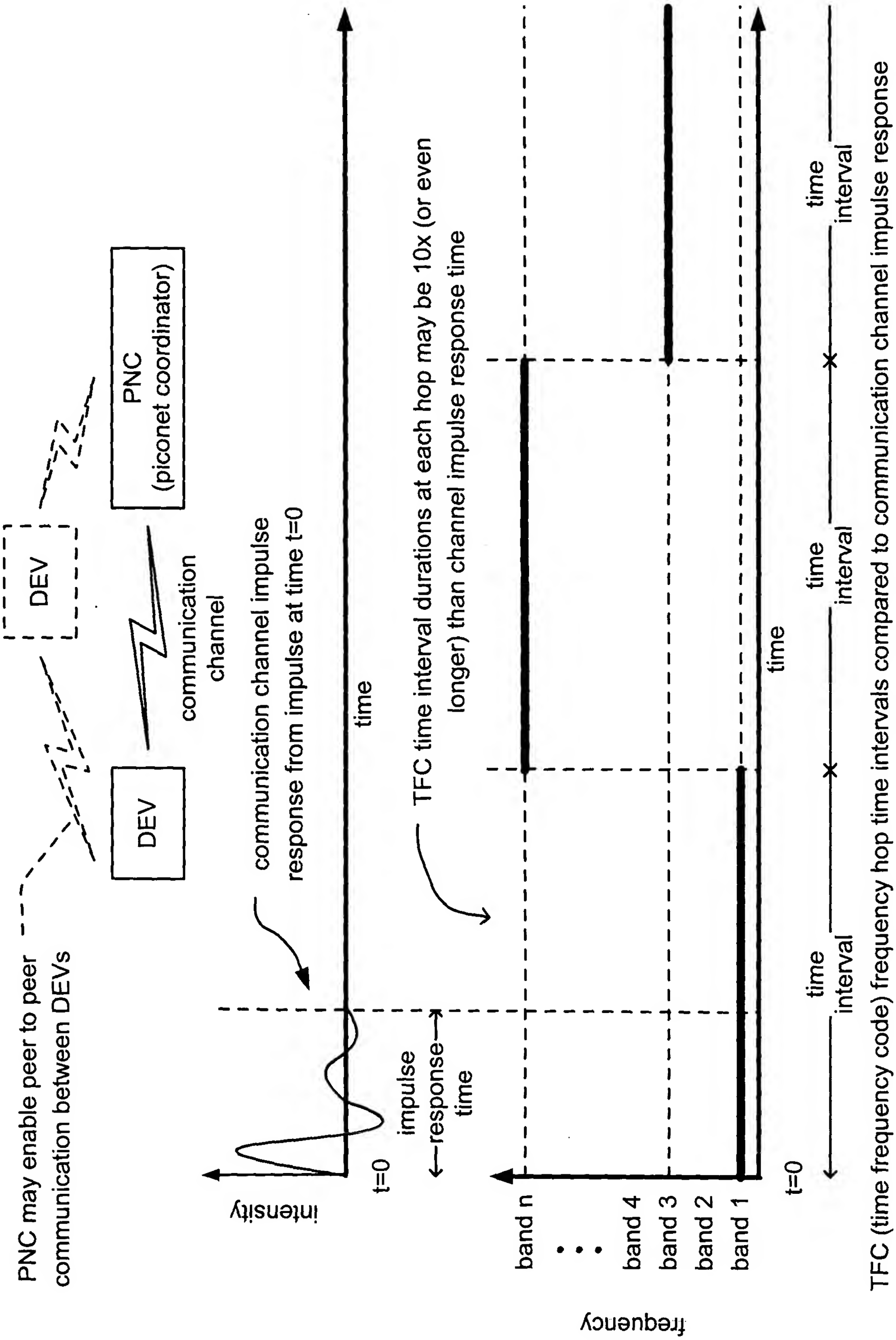

PNC
(piconet coordinator)
DEV
DEV
communication
channel
PNC may enable peer to peer
communication between DEVs
communication channel impulse
response from impulse at time t=0
intensity
t=0
impulse
response
time
time
TFC time interval durations at each hop may be 10x (or even
longer) than channel impulse response time
band n
band 4
band 3
band 2
band 1
frequency
time
t=0
time
interval
time
interval
TFC (time frequency code) frequency hop time intervals compared to communication channel impulse response

**Fig. 3**

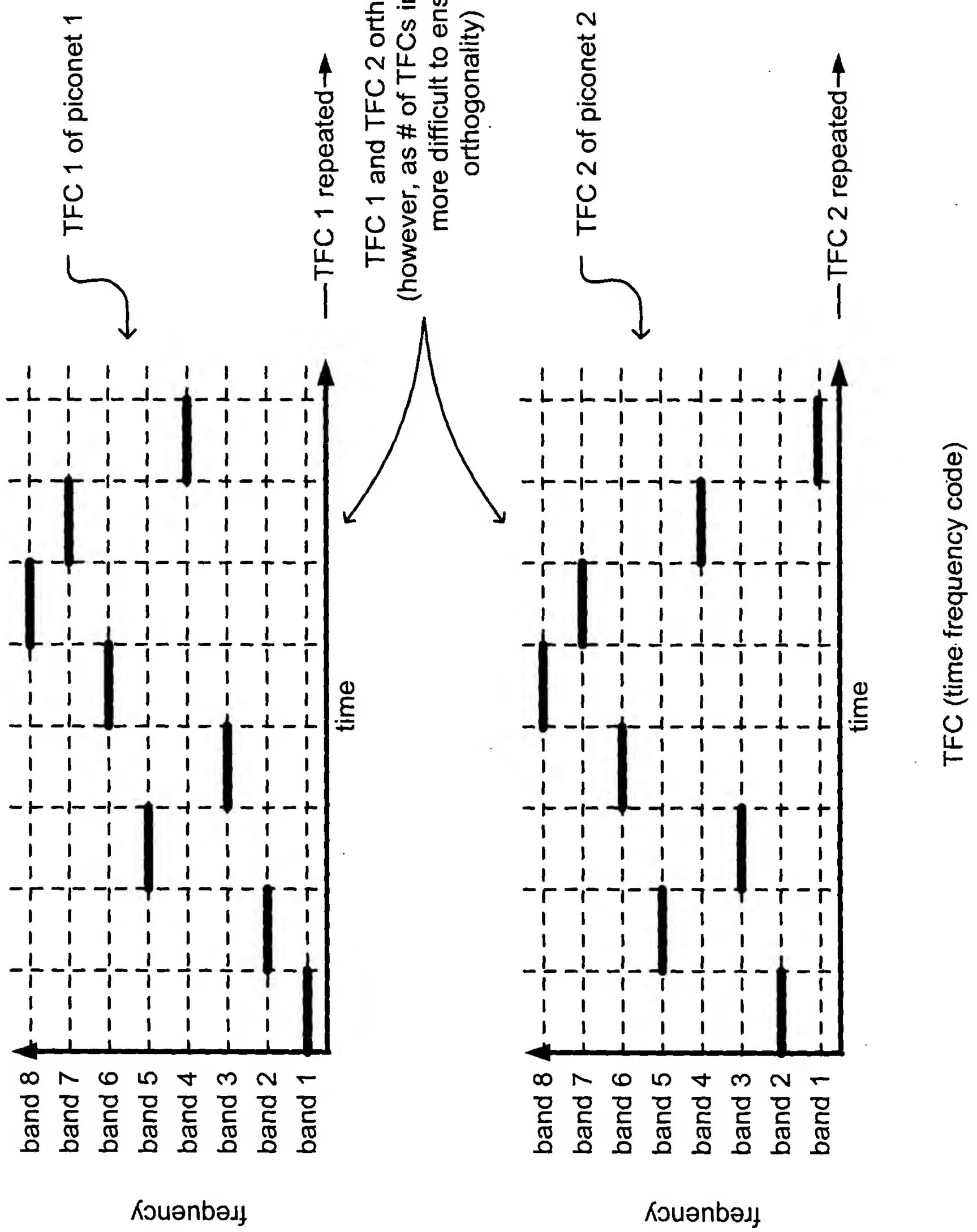
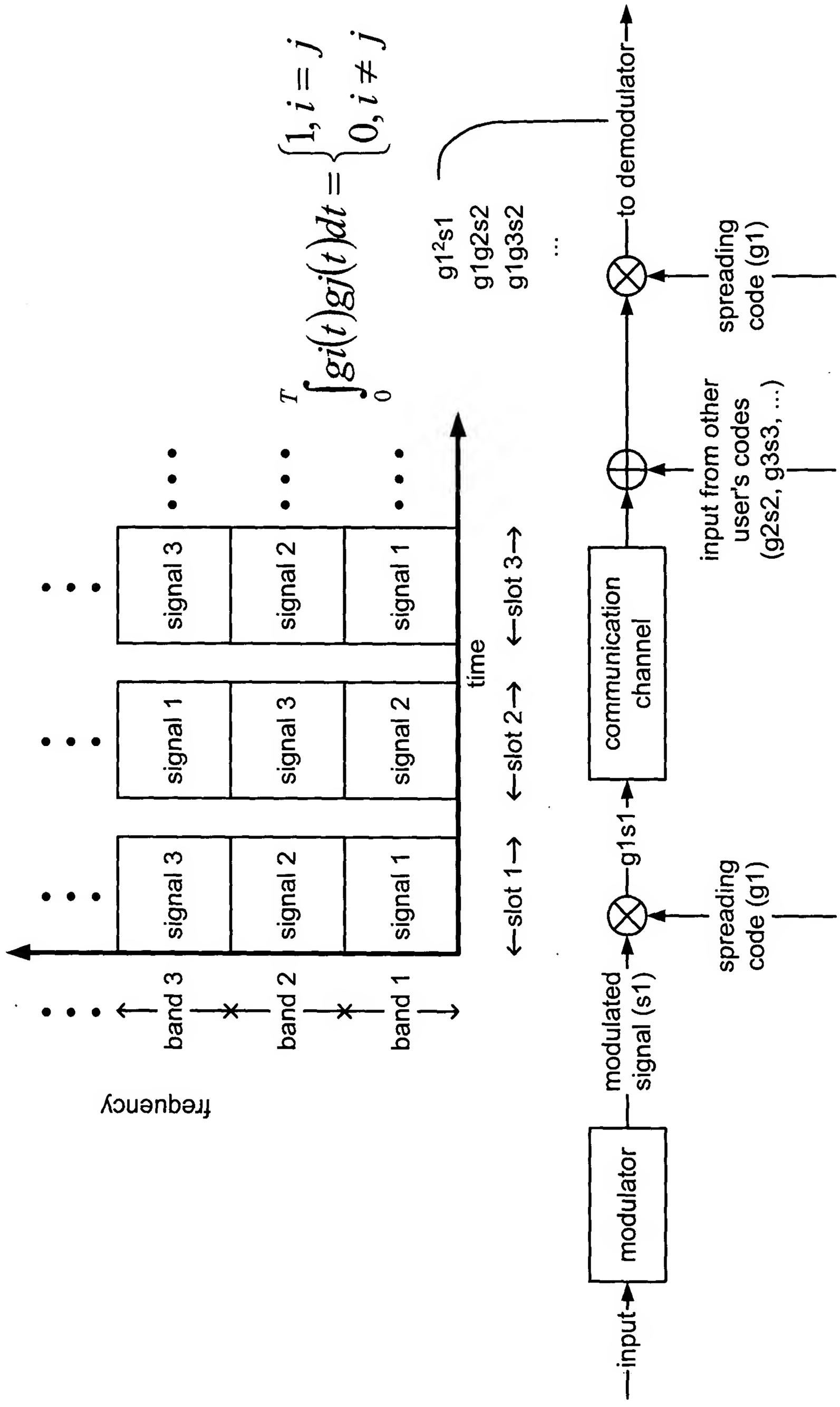

TFC 1 of piconet 1
TFC 1 repeated
TFC 1 and TFC 2 orthogonal
(however, as # of TFCs increased,
more difficult to ensure
orthogonality)
TFC 2 of piconet 2
TFC 2 repeated
time
time
band 8
band 7
band 6
band 5
band 4
band 3
band 2
band 1
band 8
band 7
band 6
band 5
band 4
band 3
band 2
band 1
frequency
frequency
TFC (time frequency code)

**Fig. 4**




CDMA (Code Division Multiple Access)

**Fig. 5**

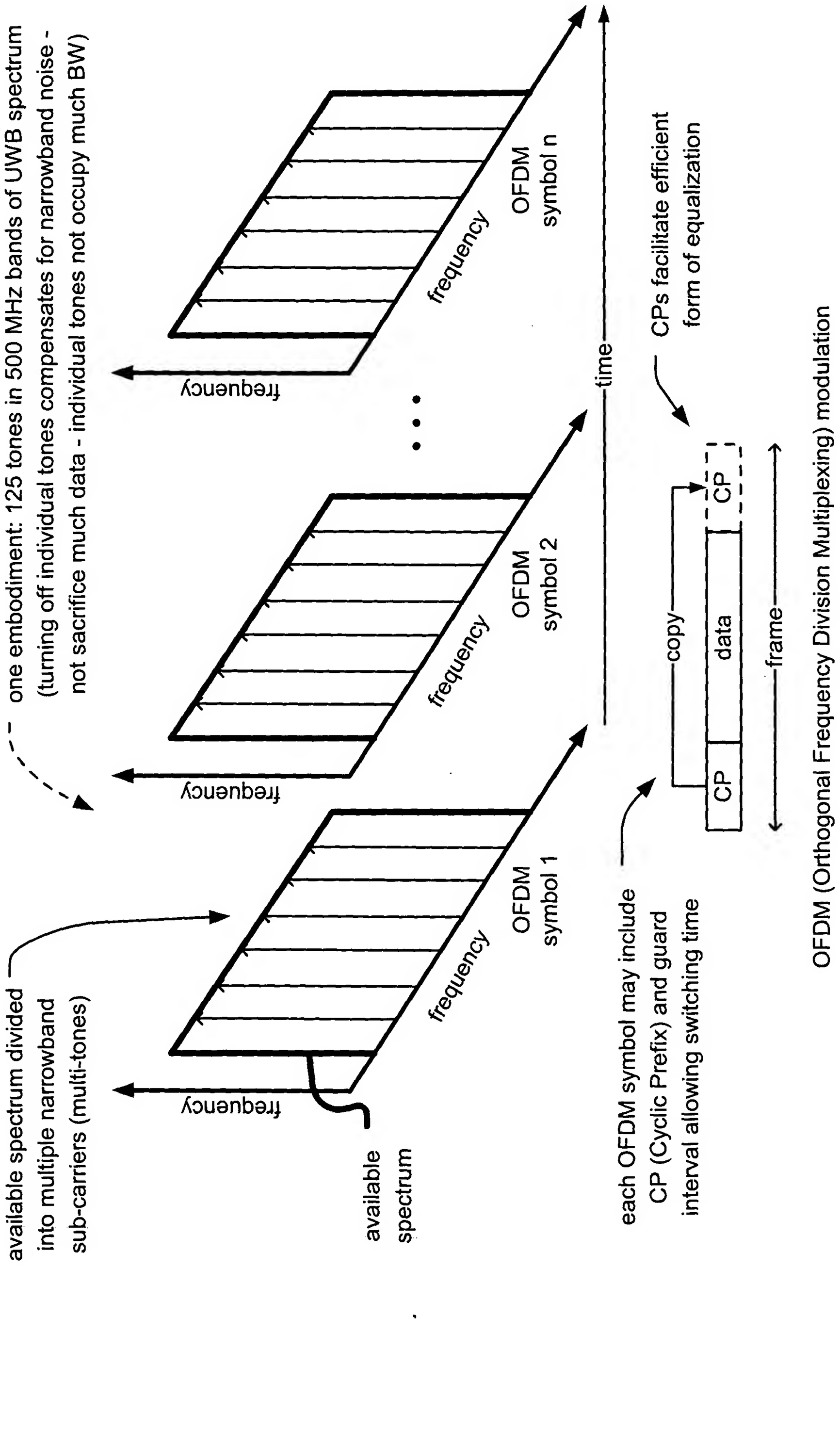

available spectrum divided into multiple narrowband sub-carriers (multi-tones)
one embodiment: 125 tones in 500 MHz bands of UWB spectrum
(turning off individual tones compensates for narrowband noise - not sacrifice much data - individual tones not occupy much BW)
frequency
available spectrum
OFDM symbol 1
OFDM symbol 2
OFDM symbol n
time
each OFDM symbol may include CP (Cyclic Prefix) and guard interval allowing switching time
CPs facilitate efficient form of equalization
copy
CP
data
frame
OFDM (Orthogonal Frequency Division Multiplexing) modulation

**Fig. 6**

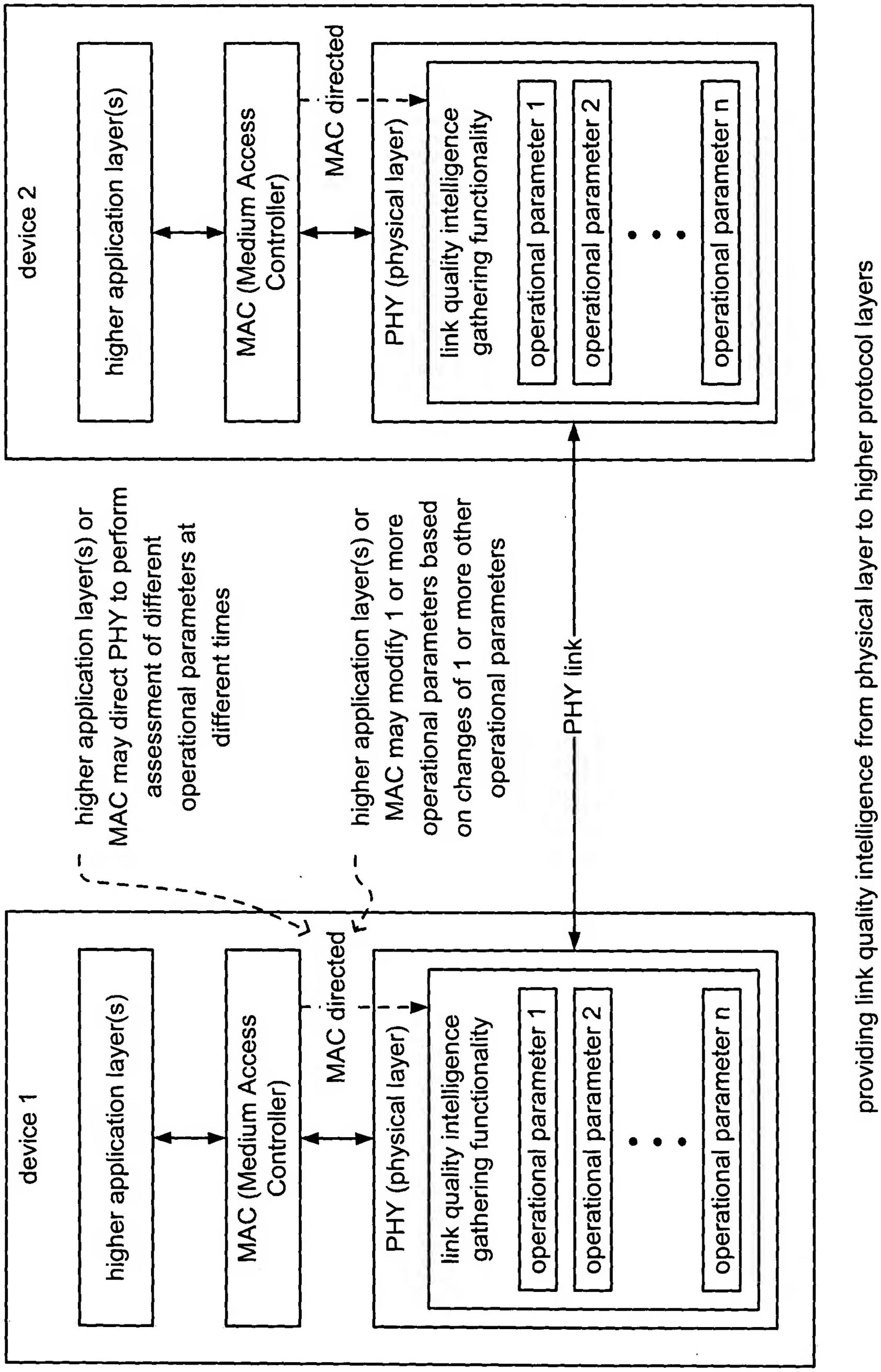

device 2
higher application layer(s)
MAC (Medium Access Controller)
MAC directed
PHY (physical layer)
link quality intelligence gathering functionality
operational parameter 1
operational parameter 2
operational parameter n
higher protocol layers
higher application layer(s) or MAC may direct PHY to perform assessment of different operational parameters at different times
higher application layer(s) or MAC may modify 1 or more operational parameters based on changes of 1 or more other operational parameters
PHY link
device 1
higher application layer(s)
MAC (Medium Access Controller)
MAC directed
PHY (physical layer)
link quality intelligence gathering functionality
operational parameter 1
operational parameter 2
operational parameter n
providing link quality intelligence from physical layer to higher protocol layers

**Fig. 7**

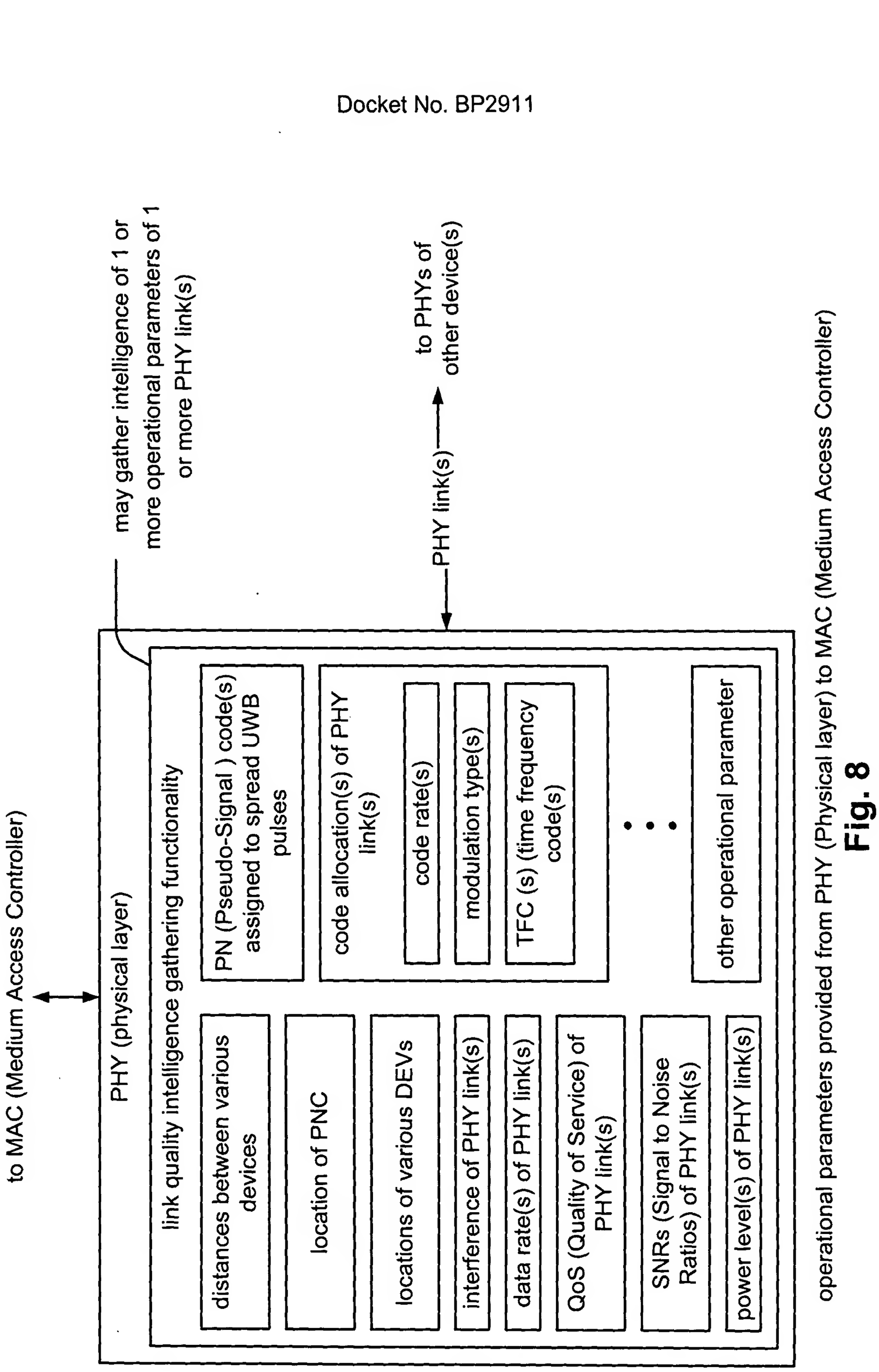

to MAC (Medium Access Controller)
PHY (physical layer)
link quality intelligence gathering functionality
distances between various devices
location of PNC
locations of various DEVs
interference of PHY link(s)
data rate(s) of PHY link(s)
QoS (Quality of Service) of PHY link(s)
SNRs (Signal to Noise Ratios) of PHY link(s)
power level(s) of PHY link(s)
PN (Pseudo-Signal ) code(s) assigned to spread UWB pulses
code allocation(s) of PHY link(s)
code rate(s)
modulation type(s)
TFC (s) (time frequency code(s)
other operational parameter
operational parameters provided from PHY (Physical layer) to MAC (Medium Access Controller)
PHY link(s) to PHYs of other device(s)
may gather intelligence of 1 or more operational parameters of 1 or more PHY link(s)

**Fig. 8**

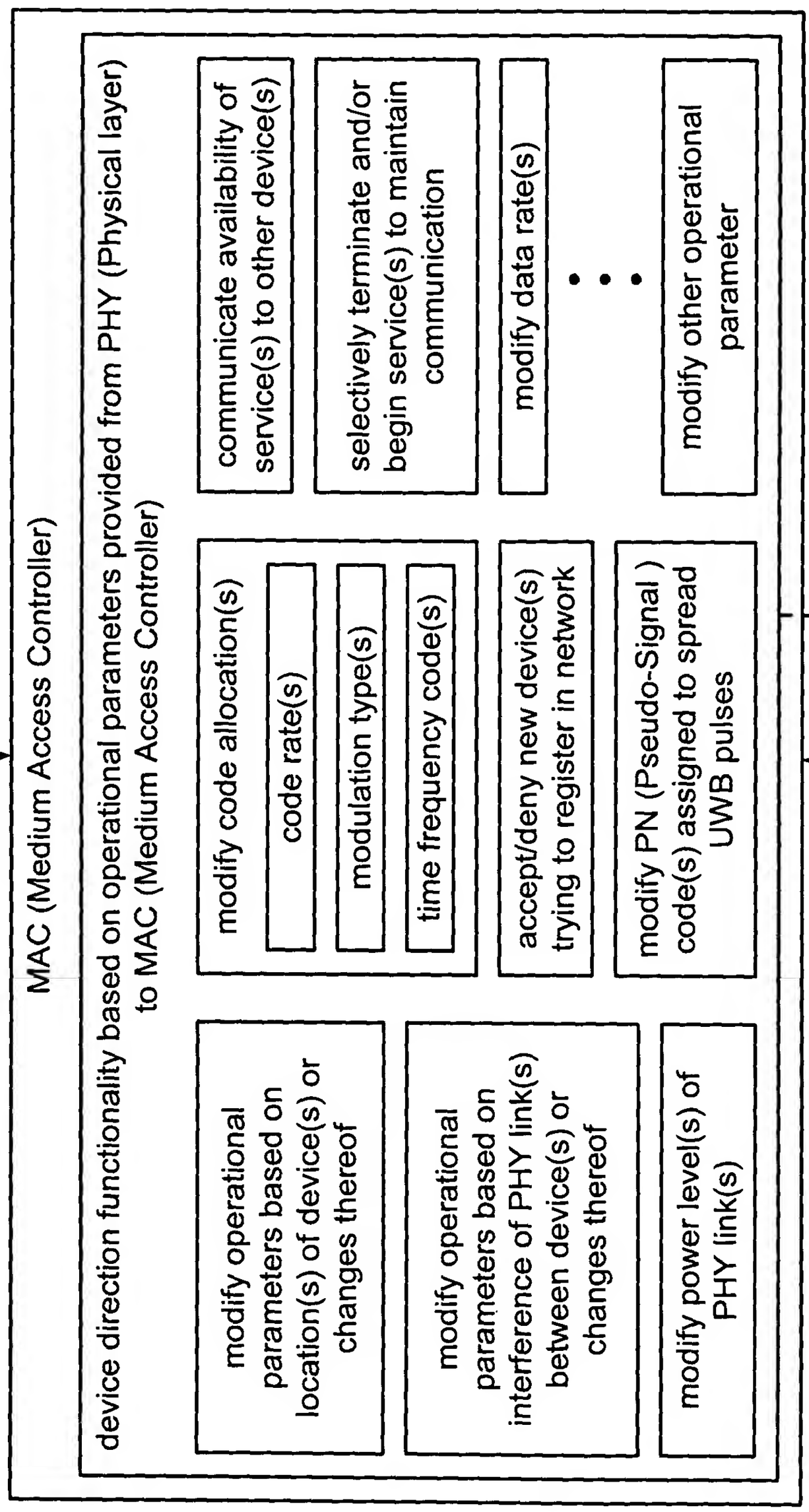

higher application layer(s) may also support similar functionality as MAC
to higher application layer(s)
MAC (Medium Access Controller)
device direction functionality based on operational parameters provided from PHY (Physical layer) to MAC (Medium Access Controller)
modify operational parameters based on location(s) of device(s) or changes thereof
modify code allocation(s)
code rate(s)
modulation type(s)
time frequency code(s)
modify PN (Pseudo-Signal ) code(s) assigned to spread UWB pulses
modify operational parameters based on interference of PHY link(s) between device(s) or changes thereof
accept/deny new device(s) trying to register in network
modify power level(s) of PHY link(s)
communicate availability of service(s) to other device(s)
selectively terminate and/or begin service(s) to maintain communication
modify data rate(s)
modify other operational parameter
MAC direction
to PHY (physical layer)
MAC (Medium Access Controller) directed device interaction with network

**Fig. 9**

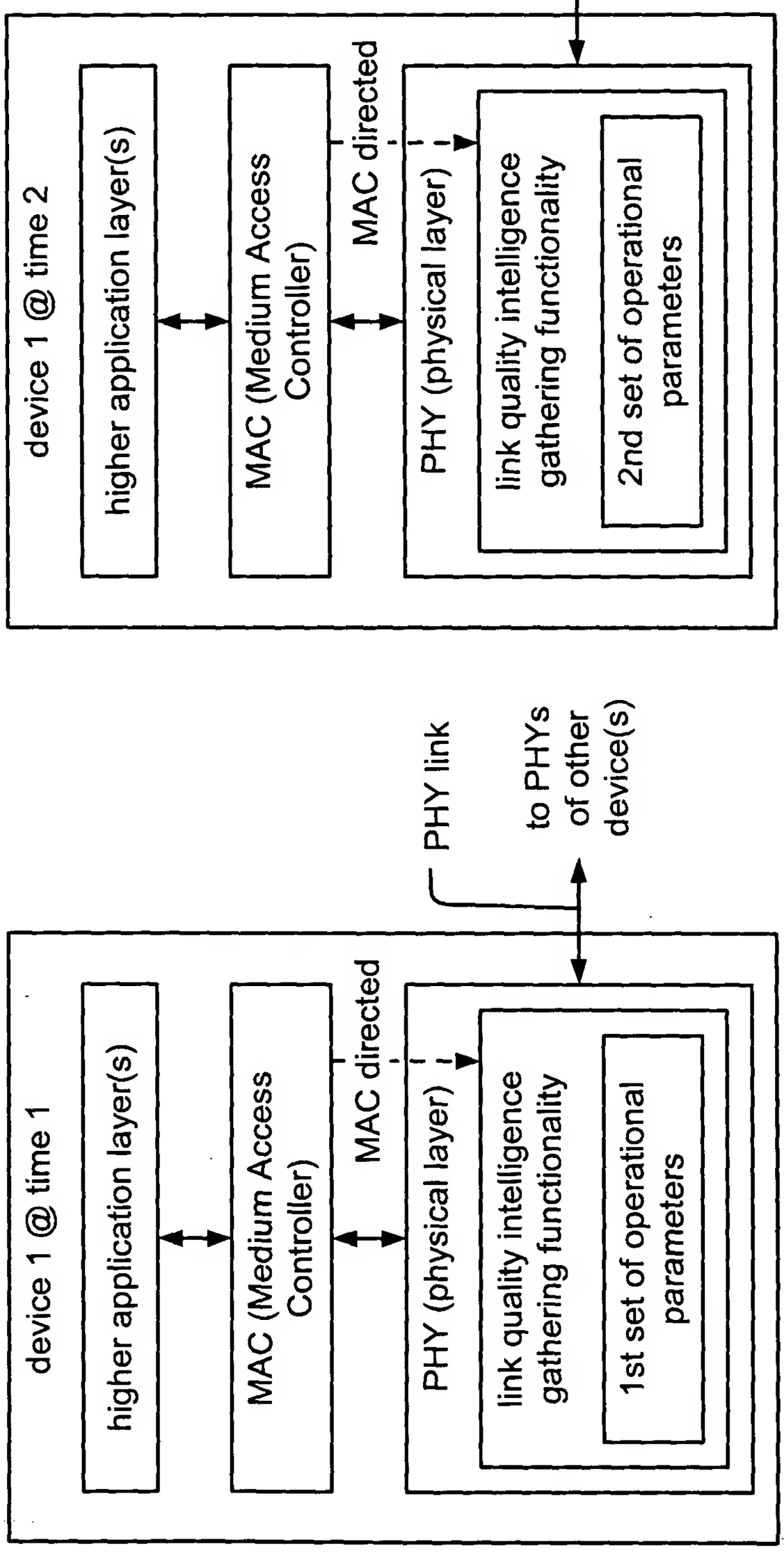

device 1 @ time 1
higher application layer(s)
MAC (Medium Access Controller)
MAC directed
PHY (physical layer)
link quality intelligence gathering functionality
1st set of operational parameters
PHY link
to PHYs of other device(s)
at time 1, higher application layer(s) or MAC processes 1st set of operational parameters to determine 2nd set of operational parameters to assess at time 2
assessing different sets of operational parameters at different times
1st set of operational parameters and 2nd set of operational parameters may include common operational parameter
device 1 @ time 2
higher application layer(s)
MAC (Medium Access Controller)
MAC directed
PHY (physical layer)
link quality intelligence gathering functionality
2nd set of operational parameters
PHY link
to PHYs of other device(s)

Fig. 10

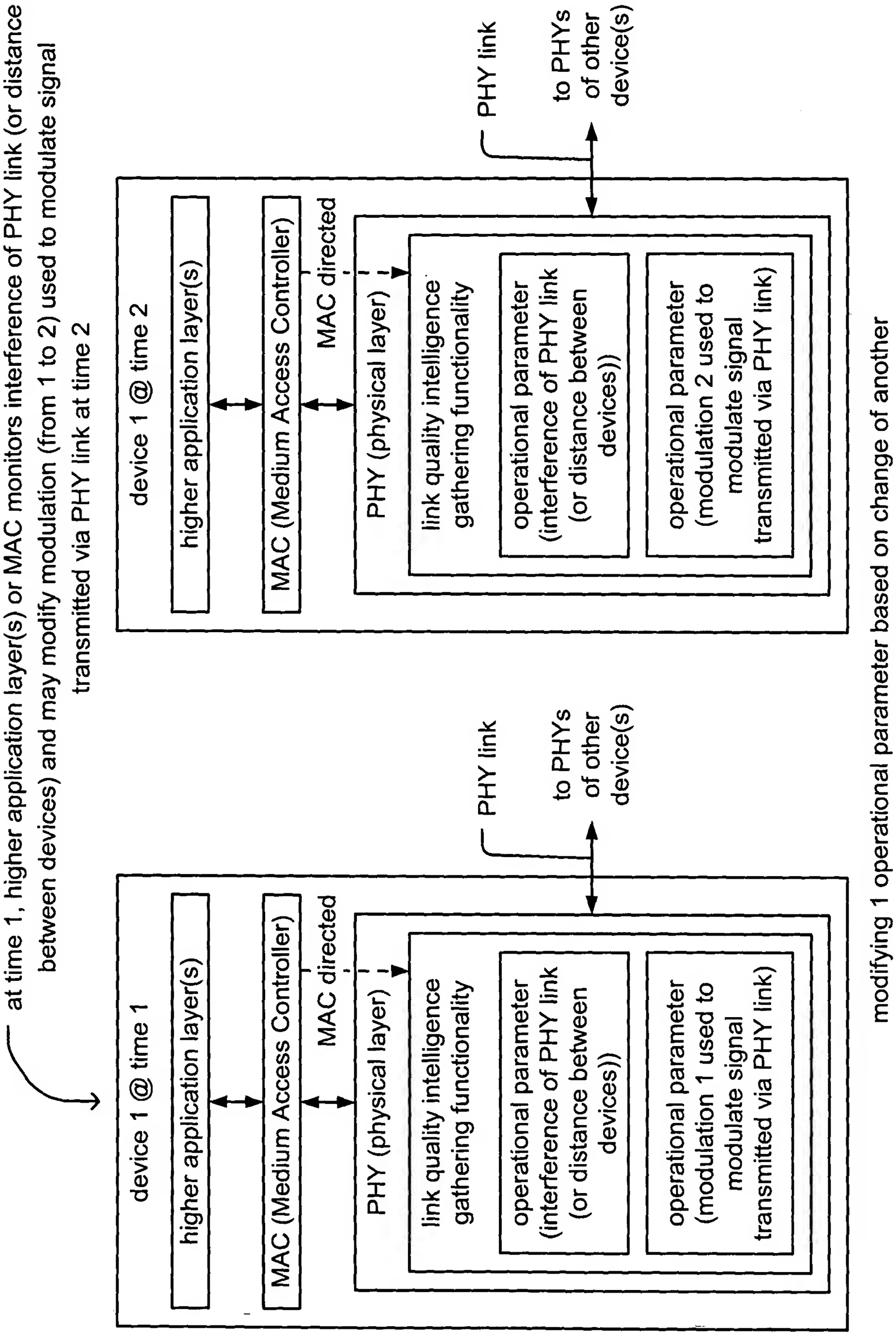

at time 1, higher application layer(s) or MAC monitors interference of PHY link (or distance between devices) and may modify modulation (from 1 to 2) used to modulate signal transmitted via PHY link at time 2
device 1 @ time 1
higher application layer(s)
MAC (Medium Access Controller)
MAC directed
PHY (physical layer)
link quality intelligence gathering functionality
operational parameter (interference of PHY link (or distance between devices))
operational parameter (modulation 1 used to modulate signal transmitted via PHY link)
PHY link
to PHYs of other device(s)
device 1 @ time 2
higher application layer(s)
MAC (Medium Access Controller)
MAC directed
PHY (physical layer)
link quality intelligence gathering functionality
operational parameter (interference of PHY link (or distance between devices))
operational parameter (modulation 2 used to modulate signal transmitted via PHY link)
PHY link
to PHYs of other device(s)
modifying 1 operational parameter based on change of another

**Fig. 11**

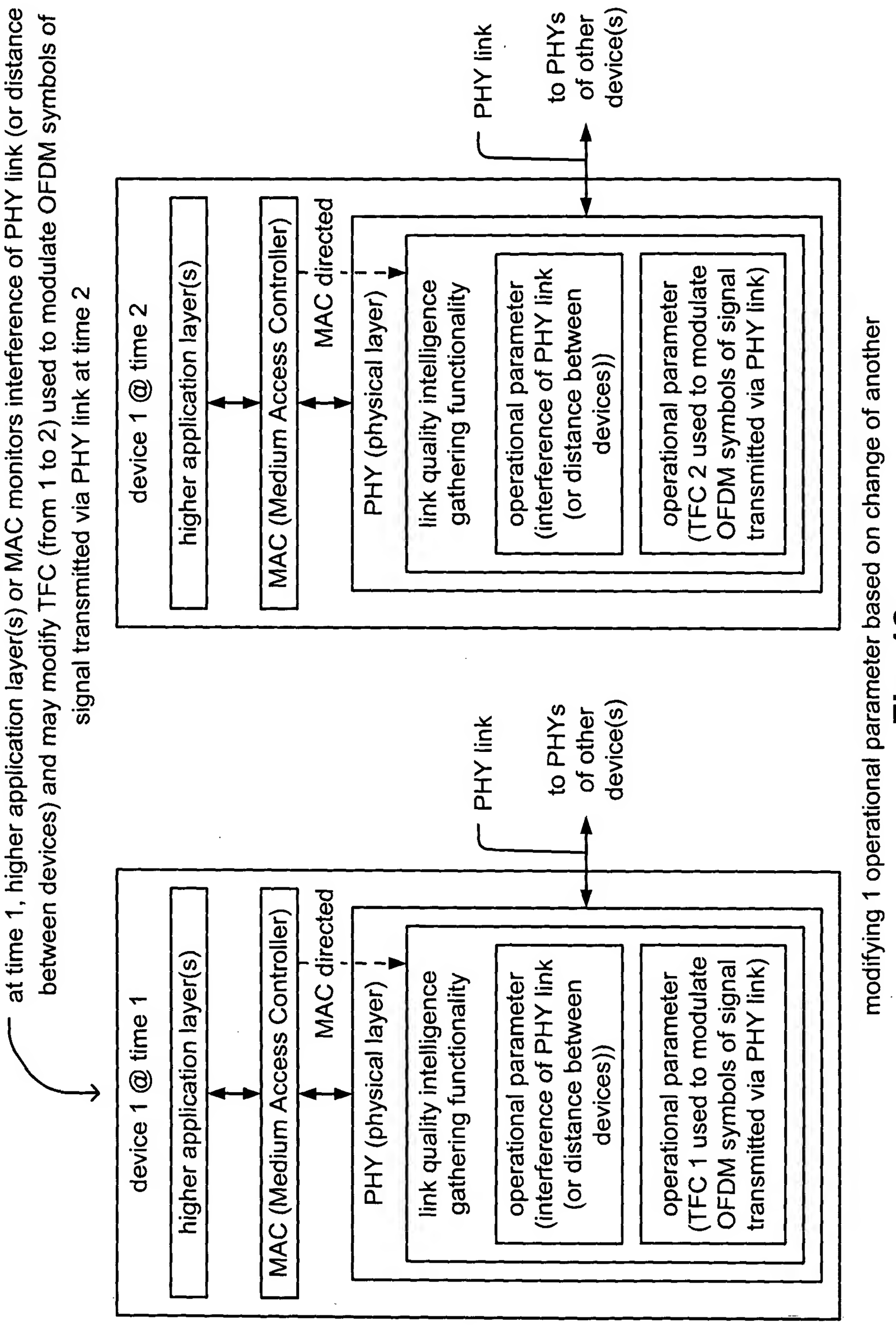

at time 1, higher application layer(s) or MAC monitors interference of PHY link (or distance between devices) and may modify TFC (from 1 to 2) used to modulate OFDM symbols of signal transmitted via PHY link at time 2
device 1 @ time 2
higher application layer(s)
MAC (Medium Access Controller)
MAC directed
PHY (physical layer)
link quality intelligence gathering functionality
operational parameter (interference of PHY link (or distance between devices))
operational parameter (TFC 2 used to modulate OFDM symbols of signal transmitted via PHY link)
PHY link
to PHYs of other device(s)
device 1 @ time 1
higher application layer(s)
MAC (Medium Access Controller)
MAC directed
PHY (physical layer)
link quality intelligence gathering functionality
operational parameter (interference of PHY link (or distance between devices))
operational parameter (TFC 1 used to modulate OFDM symbols of signal transmitted via PHY link)
PHY link
to PHYs of other device(s)
modifying 1 operational parameter based on change of another

**Fig. 12**

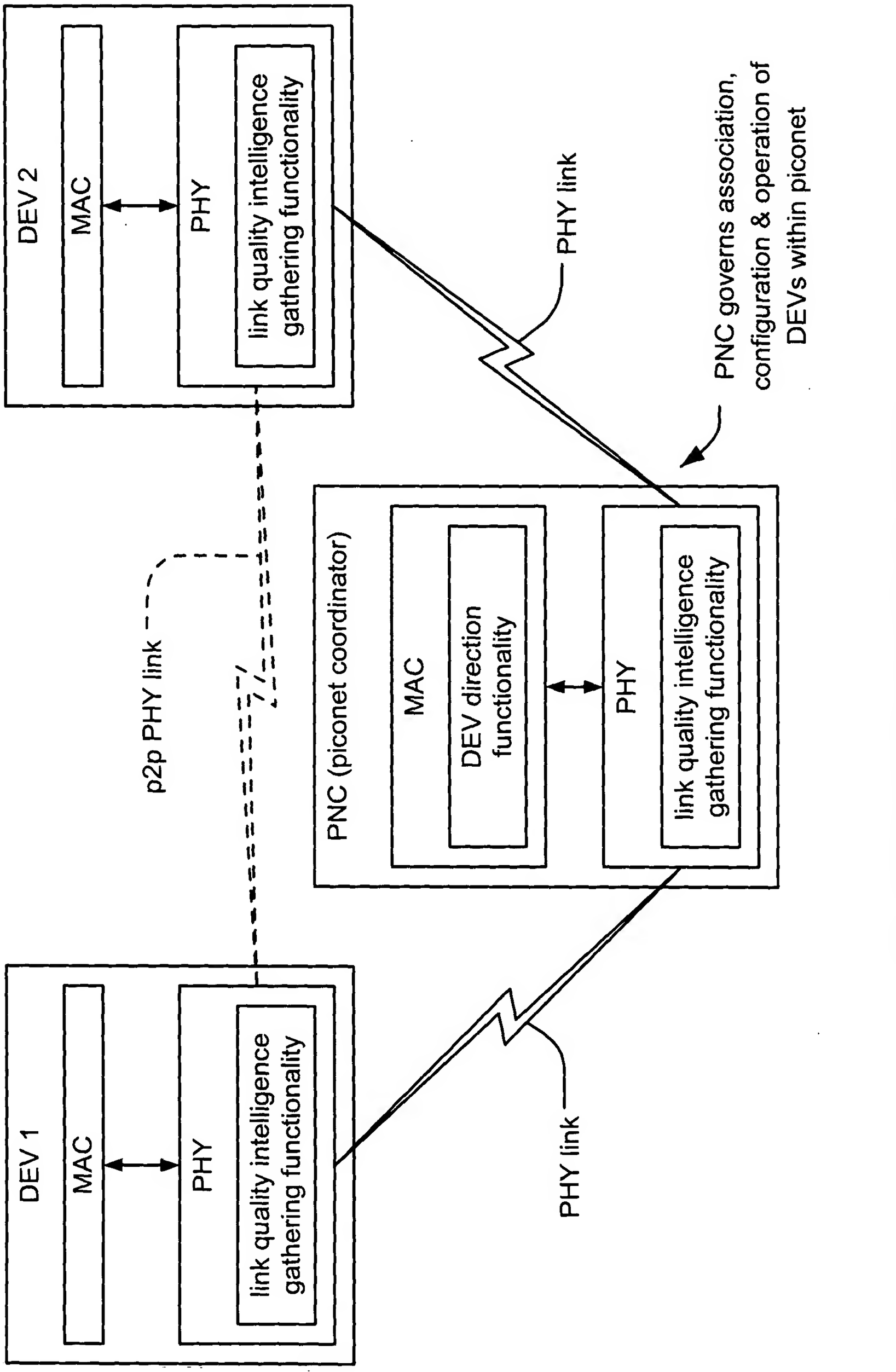
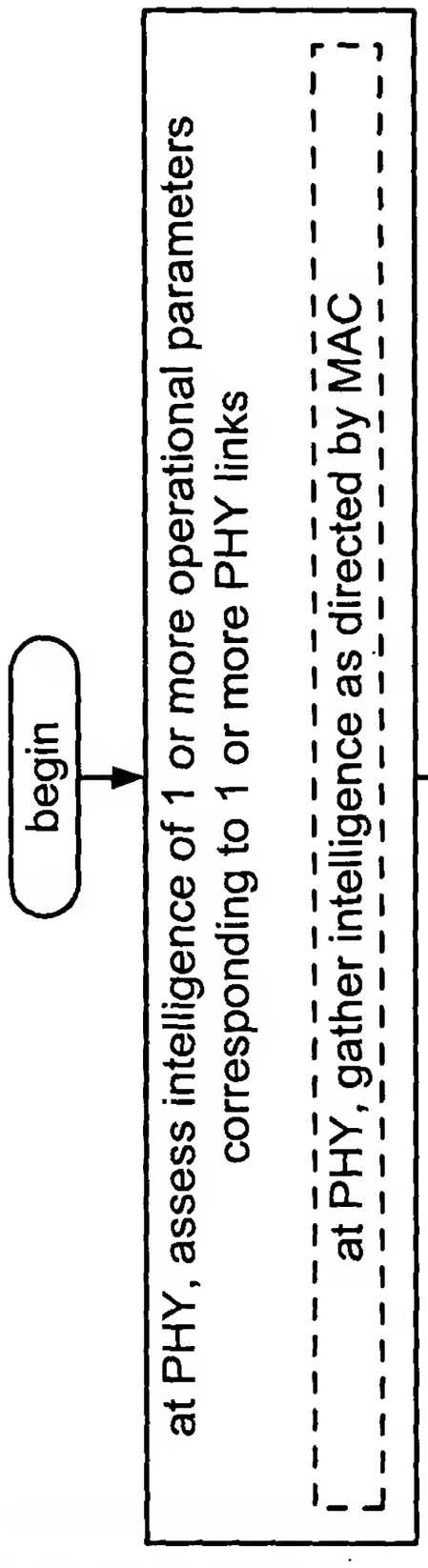
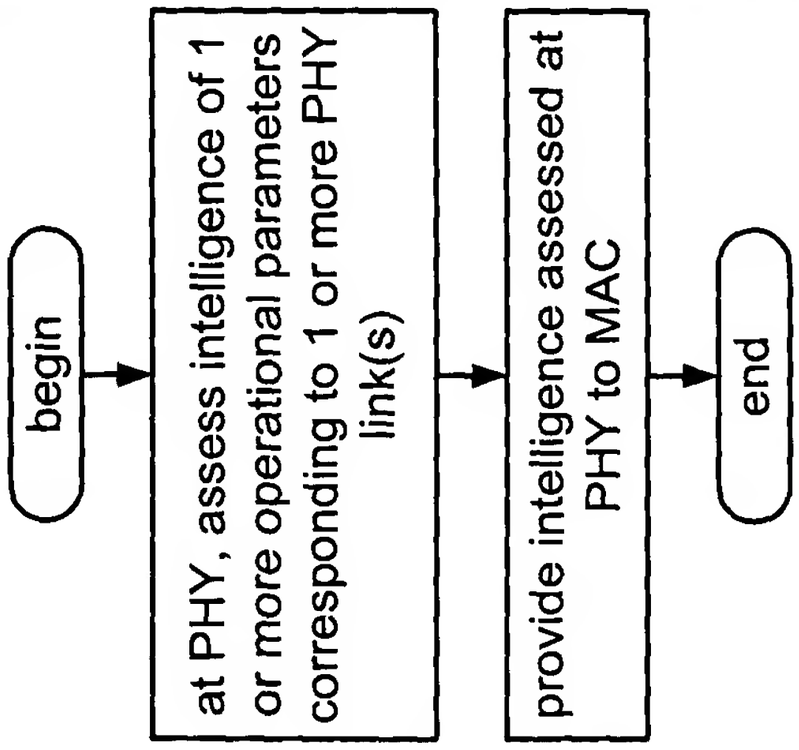

DEV 2
MAC
PHY
link quality intelligence gathering functionality
PHY link
PNC governs association, configuration & operation of DEVs within piconet
p2p PHY link
PNC (piconet coordinator)
MAC
DEV direction functionality
PHY
link quality intelligence gathering functionality
DEV 1
MAC
PHY
link quality intelligence gathering functionality
PHY link
PNC direction operation of DEVs within piconet

**Fig. 13**



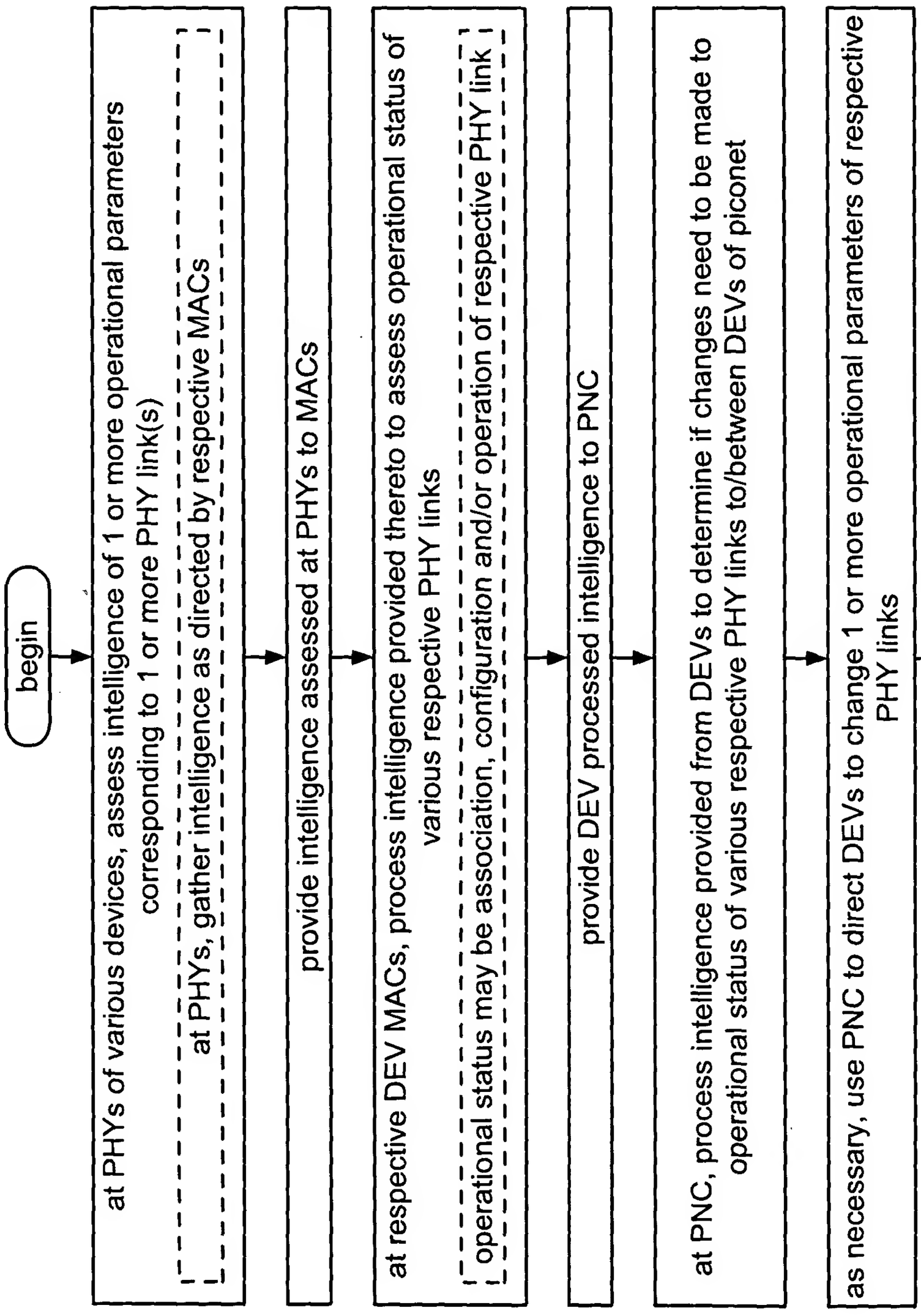

method for providing link quality intelligence from physical layer to higher protocol layers

**Fig. 14B**




method for providing link quality intelligence from physical layer to higher protocol layers

**Fig. 14A**




PNC direction operation of DEVs within piconet

**Fig. 15**